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WHAT MAKES A RADIO-AGN TICK? TRIGGERING AND FEEDING OF ACTIVE GALAXIES WITH STRONG RADIO JETS

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ABSTRACT

Although the link between activity in the nuclei of galaxy and galactic mergers has been under scrutiny for several years, it is still unclear to what extent and for which populations of active galaxies merger-triggered activity is relevant. The environments of AGN allow an indirect probe of the past merger history and future merger probability of these systems, suffering less from sensitivity issues when extended to higher redshifts than traditional morphological studies of AGN host galaxies. Here we present results from our investigation of the environment of radio selected sources out to a redshift z=2. We employ the first data release J-band catalog of the new near-IR Infrared Medium-Deep Survey (IMS), 1.4 GHz radio data from the Faint Images of the Radio Sky at Twenty-cm (FIRST) survey and a deep dedicated VLA survey of the VIMOS field, covering a combined total of 20 sq. degrees. At a flux limit of the combined radio catalog of 0.1 mJy, we probe over 8 orders of magnitude of radio luminosity. Using the second closest neighbor density parameters, we test whether active galaxies inhabit denser environments. We find evidence for a sub-population of radio-selected AGN that reside in significantly overdense environments at small scales, although we do not find significant overdensities for the bulk of our sample. We show that radio-AGN in the most underdense environments have vigorous ongoing star formation. We interpret these results in terms of the triggering and fuelling mechanism of radio-AGN.

Key words: galaxies: active – galaxies: jets – galaxies: star formation – galaxies: evolution

1. THE TRIGGERING OF RADIO-AGN

The recent decades have revolutionized our understanding of how galaxies and the supermassive black holes at their centers evolve (e.g., Springel et al. 2005, Hopkins et al. 2006). However, an ongoing debate concerns the way that active galactic nuclei (AGN) in galaxies are triggered and sustained. The temporal coincidence of the peak of cosmic nuclear and star-formation activity (e.g., Richards et al. 2006, Aird et al. 2010), as well as the predominantly very luminous AGN discovered beyond our local universe, have led to the merger-driven paradigm of AGN triggering (e.g., Sanders et al. 1988). However, with the advent of deeper extragalactic surveys this paradigm has come in question. Moderate luminosity X-ray AGN at intermediate redshifts were not found to be preferentially associated with mergers (e.g., Cisternas et al. 2011), nor to inhabit denser environments than their non-active counterparts (e.g., Karouzos et al. 2014a). While undoubtedly a fraction of AGN are triggered by mergers, the question still remains: how are different species of AGN triggered?
Here we use the population of radio-AGN as a case study to address this question. We present results about the environments and host galaxy properties of radio-AGN that help elucidate the different AGN feeding mechanisms within the broader context of galaxy evolution.

2. THE SA22 FIELD AND THE RADIO-AGN WITHIN IT

We use data from the Infrared Medium-Deep Survey (IMS; see this proceedings) at J band and the Deep eXtragalactic Survey (DXS; Lawrence et al. 2007). In addition, we utilize radio data at 1.4 GHz from the FIRST survey (Becker et al. 1995) and a deep VLA survey of part of SA22 (Chapman et al. 2004a). The combined radio flux density limit of our sample is 0.1 mJy. Finally, we also employ the full coverage of the WISE telescope (Wright et al. 2010). In total we select 913 radio-AGN over the ~ 20 deg^2 of the SA22 field out to z$\sim$ 2, based on their radio luminosity at 1.4 GHz ($\gtrsim 10^{40}$ erg s^{-1}). We use the IMS J band data to calculate the environmental density of sources based on the distance to their second closest neighbor. We define an over-density ratio for each radio-AGN based on the density ratio of the radio-AGN and a control sample of ~ 30 sources matched in redshift, J band magnitude, and $M_u - M_r$ absolute colour. In addition, we construct the spectral energy distributions (SED) of these radio-AGN, employ-

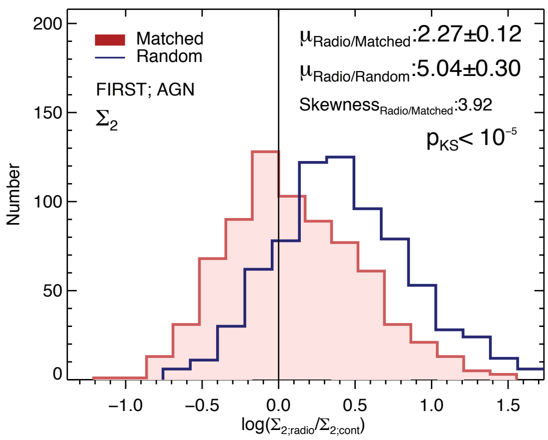

Figure 1. Second closest neighbor over-density parameter distribution between each radio source and its control sample, for all sources in the SA22-FIRST sample. The over-density ratios for the random and the matched control samples are shown with open blue and shaded red histograms, respectively. Statistical properties of the distributions, including a Kolmogorov-Smirnov two-sample test probability p_{KS}, are also shown. Adapted from Karouzos et al. (2014b).

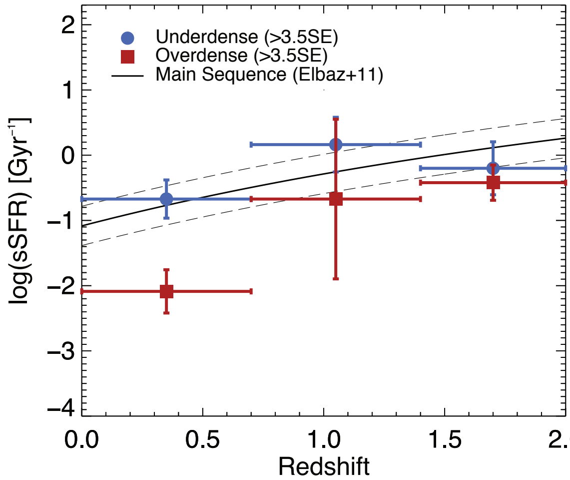

Figure 2. Average sSFR versus redshift for the OD (red) and UD (blue) radio-AGN in redshift bins. Symbols denote median values within a given redshift bin, while the error bars correspond to the standard error of the mean. The solid black line shows the calculated "Main Sequence" of star formation, as reported in Elbaz et al. (2011), while the dashed black lines show the 3σ margins of that relation. Adapted from Karouzos et al. (2014b).

ing full photometric information up to K_s band and up to WISE *W2* band for sources at redshifts < 1 and > 1, respectively[1]. By modelling these SEDs, we can characterise the star formation histories and calculate stellar masses and star formation rates (SFR) for each of the radio-AGN. From these we calculate the specific SFR (sSFR) of our sources.

3. THE NEIGHBORHOODS OF RADIO-AGN

In Fig. 1 we show the over-density ratio distribution of radio-AGN from the FIRST sample. It is apparent that the majority of them are found in rather unremarkable environments compared to their control sources (red shaded histogram). However, the distribution is strongly skewed, with a component of radio-AGN found in significantly over-dense environments. A comparison with a set of random positions within the field (blue open histogram) shows that in absolute terms these radio-AGN inhabit very dense environments.

4. STAR FORMATION IN THE HOSTS OF RADIO-AGN

We utilize the SED fitting results of the radio-AGN to look at host galaxy differences between those radio-AGN in the most over-dense (OD) and most under-dense (UD) environments in the SA22 field, in an effort to elucidate potential differences in the feeding mechanism of these sources. In Fig. 2 we plot average sSFRs in redshift bins for the two samples of OD and UD radio-AGN. We observe that the UD sub-sample shows on average higher sSFRs, consistent with or above the "Main Sequence" of star formation (e.g., Elbaz et al. 2011). The difference in sSFRs between the two sub-samples tends to disappear at redshifts > 1.

[1] Details about the photometric redshifts, environment density, and SED fitting, see Karouzos et al. (2014b).

5. WHAT MAKES RADIO-AGN TICK?

Through a study of their environments, we have shown that mergers cannot account for the triggering of the bulk of radio-AGN. On the contrary, the fact that radio-AGN in the most under-dense environments show higher sSFRs, at least in the local universe, may hint towards a completely different mechanism. Feedback from young stars, in the form of mass-loaded stellar winds, may be able to trigger and feed part of the AGN population.

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